Downloaded from orbit.dtu.dk on: May 05, 2023

DTU Library

Parametric Roll - Risk Reduction through Real-time Detection

Galeazzi, Roberto

Published in:
Container Ship Update

Publication date:
2014

Document Version
Publisher's PDF, also known as Version of record

Link back to DTU Orbit

Citation (APA):
Galeazzi, R. (2014). Parametric Roll - Risk Reduction through Real-time Detection. *Container Ship Update*, *2014*(1), 20-22.

General rights
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

DNV·GL

CONTAINER SHIP UPDATE

No **01 2014**

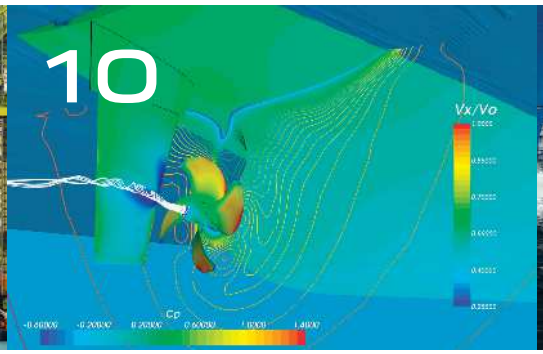
Development of large container ships

Hull optimisation

Performance monitoring

CONTENTS

Front cover photo: © DNV GL – Per Sverre Wold-Hansen



Text: Roberto Galeazzi, Associate Professor, Technical University of Denmark
Contact: Gaute.Storhaug@dnvgl.com

PARAMETRIC ROLL

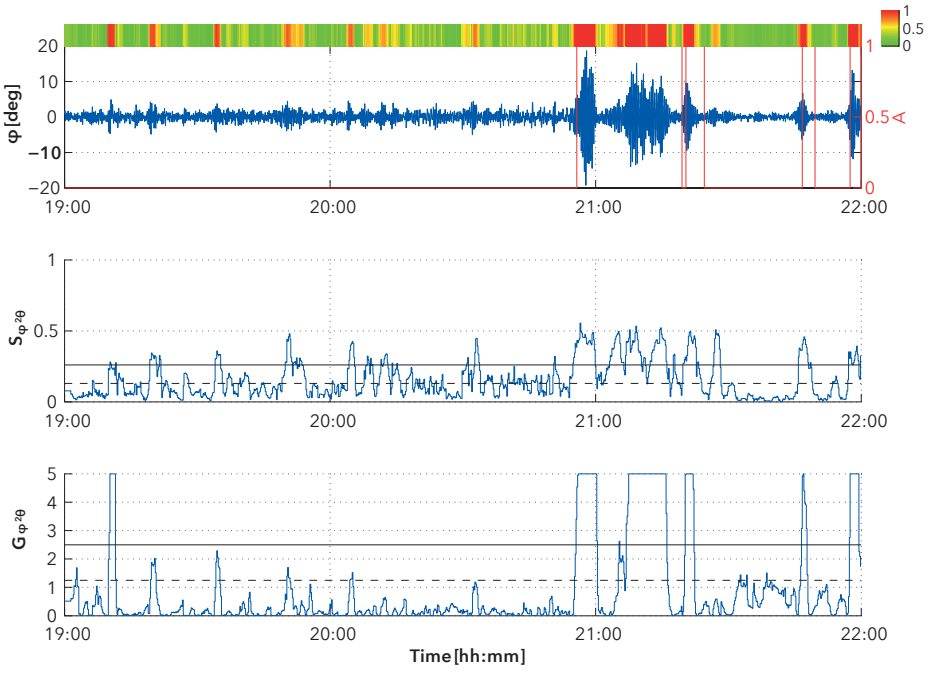
– RISK REDUCTION THROUGH REAL-TIME DETECTION

PAROLL is an innovative condition-monitoring system for the timely detection of parametric roll on merchant vessels. It has been invented and developed by the Technical University of Denmark. DNV GL and Wallenius Marine have supported the development and full-scale validation of this monitoring system.

Parametric roll in head seas is nowadays a well-known resonance phenomenon that threatens a ship's stability by inducing rapidly growing extreme roll motion, and hence may cause considerable damage in terms of cargo losses, hull integrity and crew safety. Significant research followed the multimillion-dollar incidents suffered by the APL China in 1998 and Maersk Carolina in 2003. Since then, DNV GL has actively contributed to the understanding of the phenomenon's root causes in order to improve the operational safety of merchant vessels.

In 2006, the article "Parametric Rolling – a problem solved?" was published in the DNV Container Ship Update. In this, DNV GL Vice President Knut Døhlie made a clear analysis based on the know-how accumulated by DNV through scrutiny of ships' motion data and research regarding container-ship seakeeping. Analysis of Pacific and Atlantic passages revealed that the availability of weather routing systems and implementation of navigation strategies could mitigate the risk of parametric roll occurring by sailing across routes that minimize the vessel's exposure to head-sea conditions. This approach completely disregarded the physics of the phenomenon based on frequency and phase synchronization between roll and pitch motions and aimed at preventing parametric roll by avoiding head-sea conditions. Sometimes, however, head sea is simply where you have to go.

Roberto Galeazzi, Associate Professor, Technical University of Denmark



Parametric roll – triggering conditions
Parametric roll is a ship dynamic stability problem that affects large merchant vessels such as container ships and car carriers. Empirical conditions have been identified that may trigger parametric roll:

- The period of the encounter wave is approximately equal to half of the natural roll period
- The wavelength is between 1 to 2 times the ship length
- The wave height is greater than a ship-dependent threshold
- The ship's roll damping is low

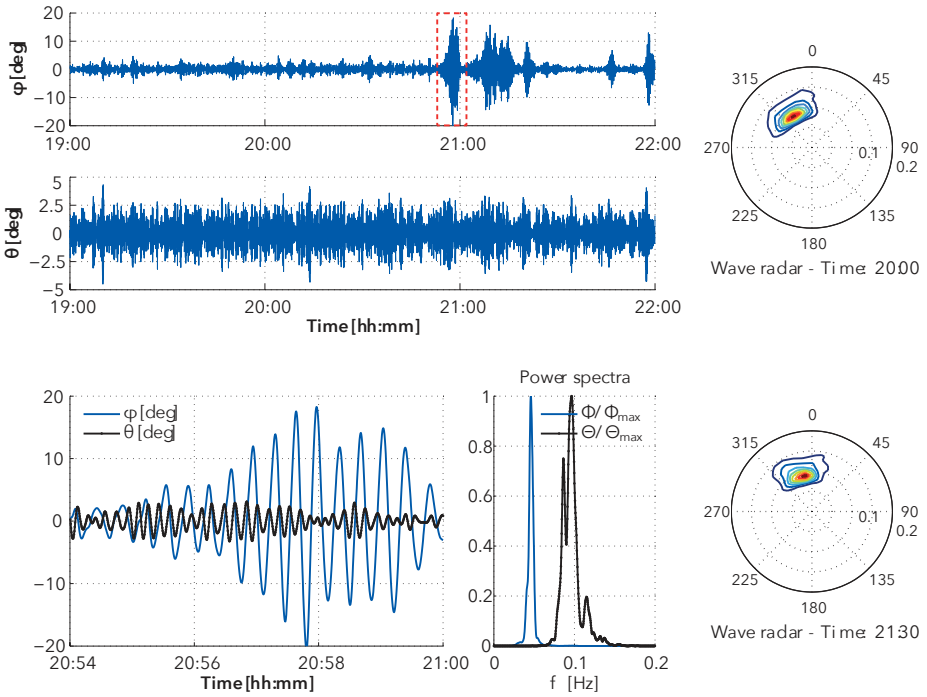
When these conditions are met and the ship sails in moderate to heavy longitudinal or oblique seas, then the wave passage along the hull and the wave-excited vertical motions result in variations of the underwater hull geometry, which in turn change the roll-restoring characteristics.

Døhlie pointed out that, although ensuring a safe passage is certainly important, it is also significant to assess the effects that this strategy has on schedule reliability and fuel consumption. Hence, he identified the need for second-generation warning systems to not only provide operational guidance in the form of polar diagrams to indicate the risk of parametric roll based on the combination of the ship's forward speed and heading, but also monitor the presence of the physical conditions that trigger parametric roll.

The PhD project Autonomous Supervision and Control of Parametric Roll Resonance (2006–2009), run at the Technical University of Denmark by Ass. Professor Roberto Galeazzi under the supervision of Professor Mogens Blanke and in collaboration with Ass. Professor Niels K. Poulsen, responded to this call for innovation by investigating signal-based detection methods which could extrapolate from ship-motion measurements the existence and persistence of the conditions for parametric roll to unfold. The research project resulted in PAROLL, a patented condition-monitoring system. Initial testing of data from model tests performed by Dr Gaute Storhaug – DNV GL Principal Specialist – showed the potential of the detection algorithms. However, to obtain robust routines, extensive testing on real full-scale motion data with and without parametric roll was paramount.

◂ Fig. 1 A 2,800 TEU container ship experiences parametric roll while crossing the Atlantic. The wave radar and spectral analysis show that the wave peak period is close to half the natural roll period. The time analysis confirms that before and during the first parametric roll event, roll and pitch are synchronized in phase.

▸ Fig. 2 Detection of parametric roll events on board a 2,800 TEU container ship. The risk index informs the crew that conditions for the triggering of parametric roll are present from about two hours prior to the large event occurring a few minutes before 21:00.



The development has continued through a Proof-of-Concept project in collaboration with the Norwegian University of Science and Technology (NTNU) and DNV GL as an industrial advisor; later on Wallenius Marine entered the project with their know-how regarding ship operators. The research collaboration with DNV GL and Wallenius Marine allowed the unique opportunity to finally test and validate the PAROLL monitoring system on large full-scale motion data sets.

PAROLL has also attracted the interest of providers of decision-support systems such as Amarcon, a member of the ABB group, which is integrating it as a part of its ship-motion monitoring and advisory system.

PAROLL: real-time detection of parametric roll

PAROLL is a novel condition-monitoring system that timely detects the development of parametric roll on board merchant vessels relying on low-cost motion sensor information. PAROLL implements signal-based automated detection algorithms, which extrapolate information about the levels of frequency and phase synchronization between the roll and pitch motion.

Two statistical change detectors are at the core of PAROLL: the spectral correlation and the phase synchronization detectors. The first assesses if the natural roll period is approximately twice the period of the pitch oscillation that in turn reflects the wave-encounter period. The second monitors if the roll and pitch motions are synchronized in phase or, quoting Knut Døhlie, if "the roll and pitch peaks are lining up". If both detectors' outputs are above their thresholds, the monitoring system issues an audible alarm.

To provide the crew with an intelligible system that gives adequate information from an operational perspective, the output of the monitoring system has been enhanced with a colour-coded risk coefficient which provides a real-time measure of closeness to a parametric-roll event by combining the current outputs of the two detectors. The colour-coded risk coefficient can help generate a state of alert for the navigator and will allow the crew to start taking pre-emptive actions to counteract parametric roll and mitigate its effects before the phenomenon unfolds to its possibly devastating magnitudes.

From an operational viewpoint, it is also important not to increase the level of nuisance on the bridge, where several other decision-support systems are integrated. Due to this, PAROLL has been further enhanced with a check-of-the-roll amplitude, which lastly is used to determine whether to issue an alarm. The selection of the roll level that serves as a final alarm threshold should be based on firm investigations into the officers' attitudes and it can therefore be tuned on board to achieve the best balance between early alerts and avoiding unnecessary alarms on the bridge. It is noted that the visual warning level is exclusively based on the risk coefficient calculated from the outputs of the two detectors, while it is solely the audible alarm that can be adjusted to users' needs via the roll amplitude level parameter.

It is important to emphasize that both detectors only use the measurements of the pitch and roll angles provided by the on-board IMU. No knowledge about the specific vessel being monitored is needed, making the PAROLL system portable and robust against ship-model uncertainties.

Full-scale validation on container ships and LCTCs

A full-scale validation of the PAROLL monitoring system was finalized during the first quarter of 2014. This was uniquely possible thanks to the valuable collaboration with DNV GL and Wallenius Marine, which have provided long-term motion data for two different vessels: selected parts of data from a 2,800 TEU container vessel for which data were available over a two-year period, and motion data from all the voyages of a large car carrier during a one-year period. Further, motion data from two of the parametric roll events reported in the literature have been made available by Wallenius Marine.

The validation has been a true success, showing that PAROLL is effectively a robust and reliable solution for the timely detection of parametric roll; confirming the already promising results obtained earlier on model tests data. In approximately 70% of the cases where parametric roll determined motions larger than ten degrees, PAROLL provides an alarm as soon as five to 40 roll cycles before the maximum roll amplitude are achieved, meaning that the crew has between 1.5 and 12 minutes to take pre-emptive actions.

From the investigations of motion data from the large car carrier and container vessel, it is possible to conclude that parametric roll is far more common than is reported. With PAROLL, timely detection is finally available so that remedial actions can be taken well before parametric roll develops to severe magnitudes. ▮

SAFER, SMARTER, GREENER

www.dnvgl.com